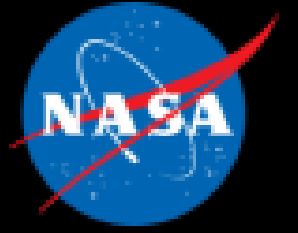


# Using A Model-Based Systems Engineering Approach For Exploration Medical System Development

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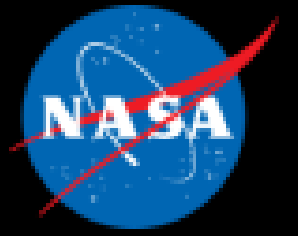
# Introduction

- NASA's Human Research Program's Exploration Medical Capabilities (ExMC) element is defining the medical system needs for exploration class missions.
- Our approach is to:
  - Establish collaborative tools to support the model infrastructure,
  - Capture stakeholder needs,
  - Design of the model architecture and emerging technical content,
  - Interact with owners of related models to coordinate model expansion.

## Mission Statement

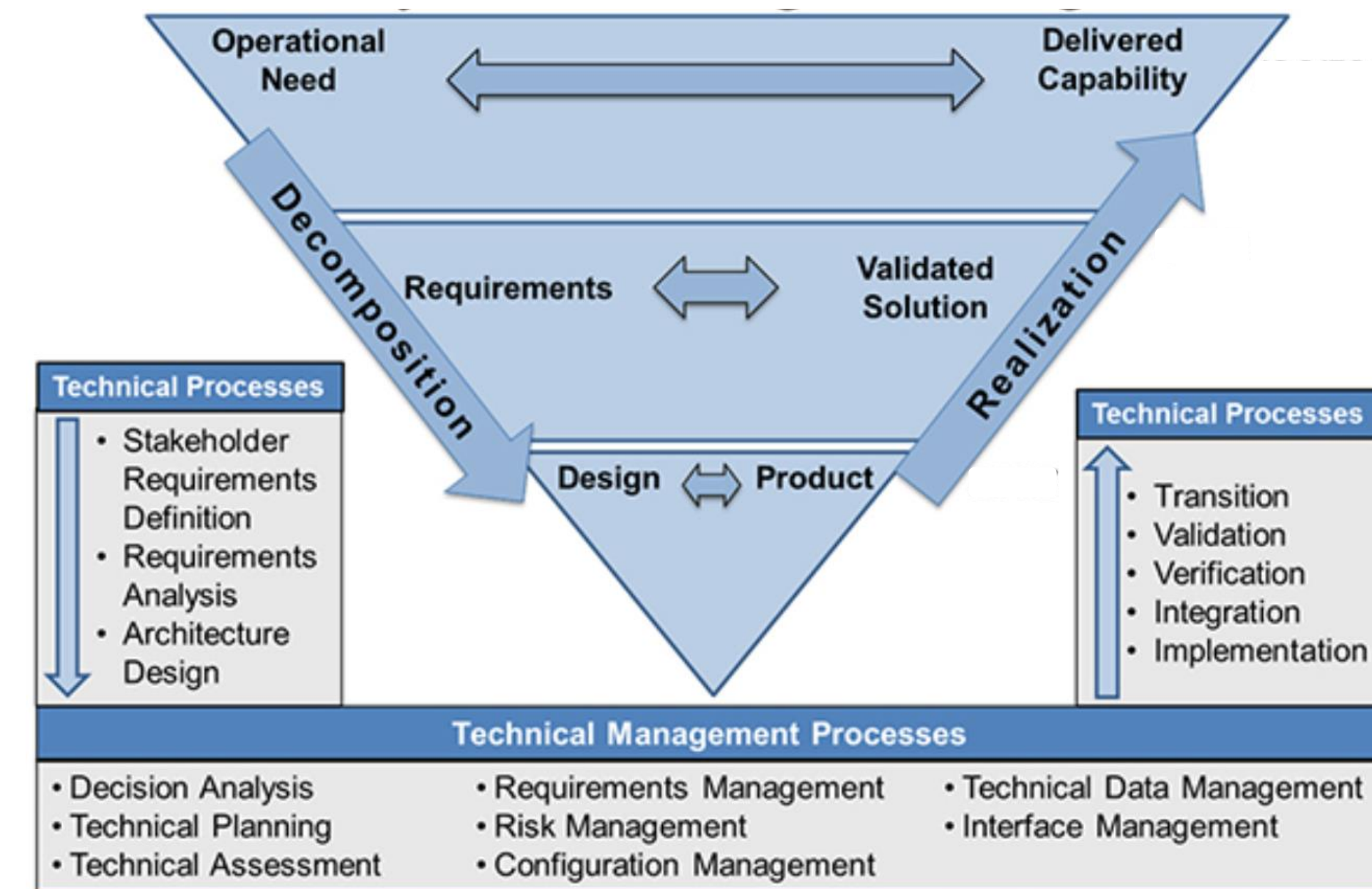
*Define, develop, validate, and manage the technical system design needed to implement exploration medical capabilities for Mars and test the design in a progression of proving grounds.*





# Model-Based Systems Engineering (MBSE)

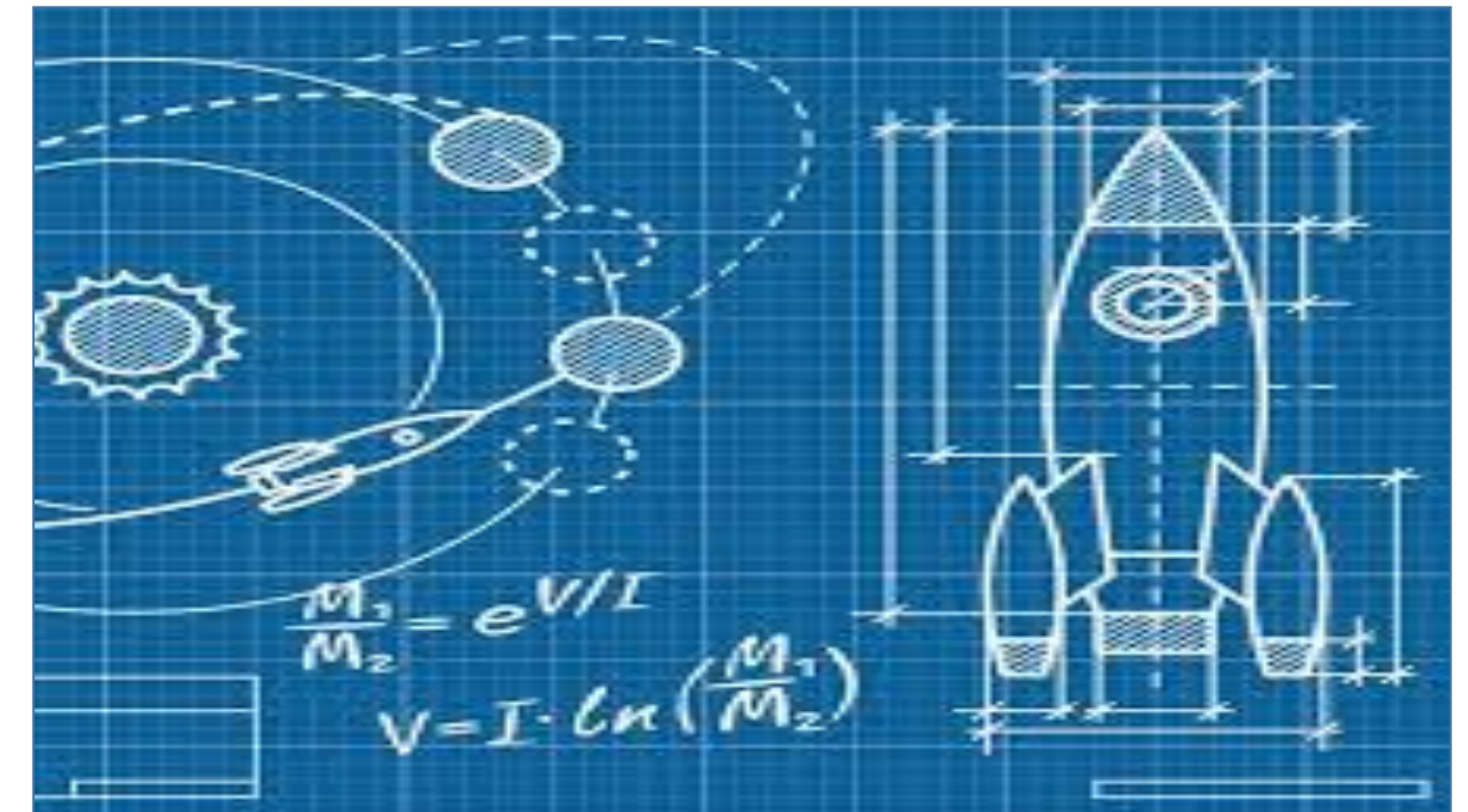
- The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.<sup>1</sup>



*Emphasis is on controlling the model of the system rather than controlling documentation about the system*

# Context and Approach

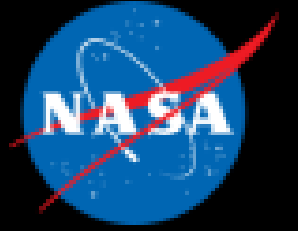
- Strive to have the team share a common mental model of the stakeholder needs, approach, and expected outcomes.
- Control, measure and report progress of technical solution throughout the project lifecycle including requirements, analysis, design, implementation, verification and operations of the system.
- Abstraction that contains only the details needed to address the intended use of the model.
- Not an analytical model.
- Team attended training courses in use of the SysML language, and a SysML Methodology Course together with other modeling groups with which we would integrate future work.



*A system model is like a building blueprint that specifies the system to be implemented*



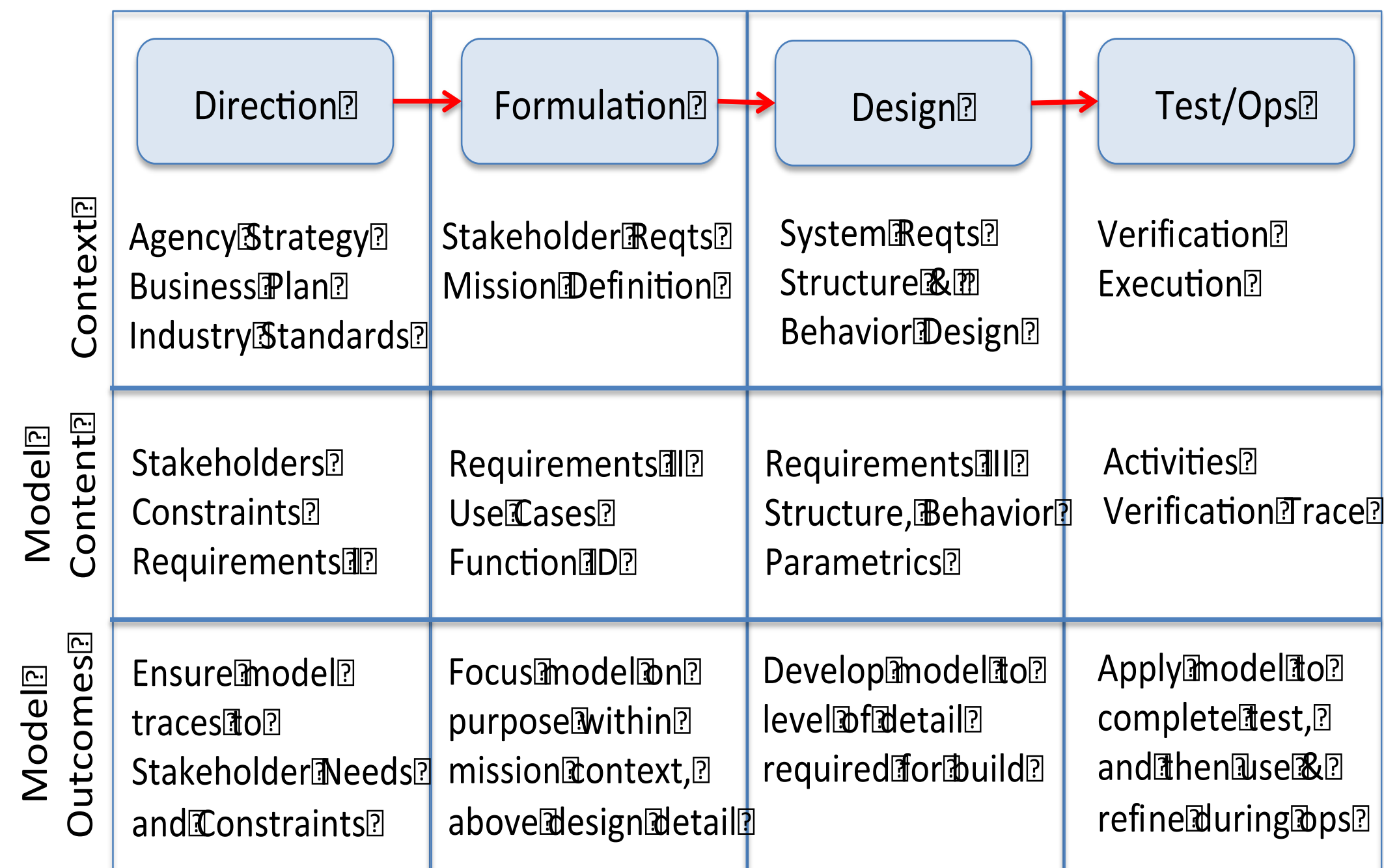
# Infrastructure



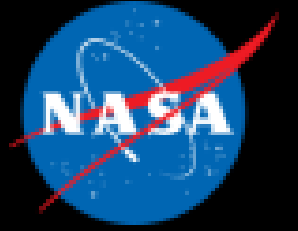
- Model infrastructure is an important foundational element and forms the underlying framework to implement MBSE.
- Infrastructure design will have long- term consequences and impact the effectiveness of the overall modelling effort.
- Systems Modeling Language (SysML) as the modeling language to support this work.
- NASA-wide teamwork server in use, and allows the geographically diverse and cross-agency group to readily access the working model.
- Roles and responsibilities of model team members were established.



# Guide Model Development

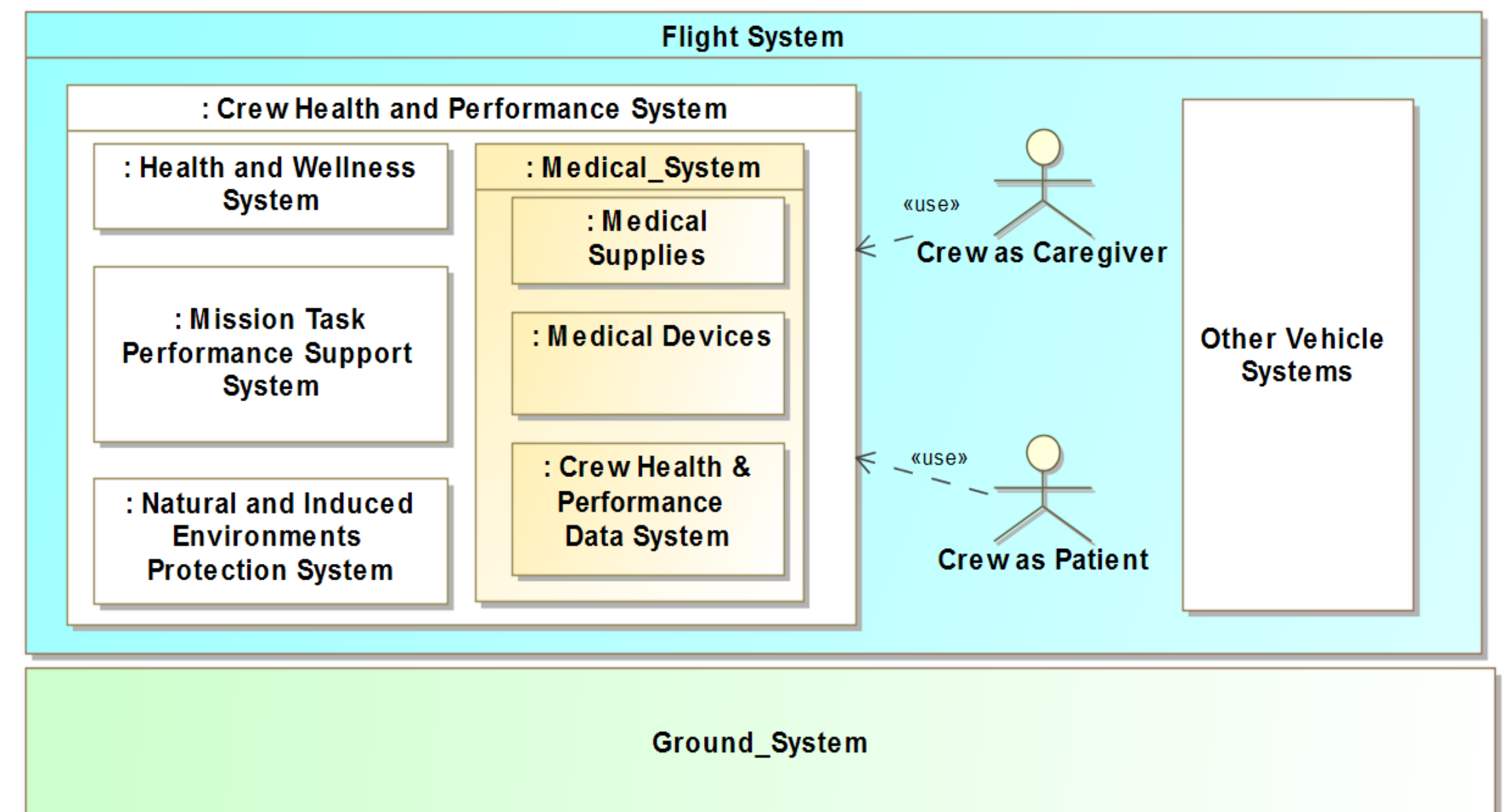


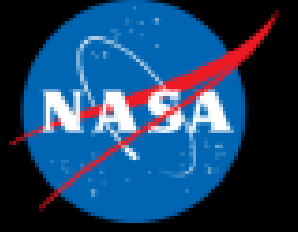
- Guidance on model development was organized into 4 generic life cycle development phases.
  - Defining the *Context* and activities in each phase of the project lifecycle, to clarify the level of detail expected in the model,
  - Identifying the *Model Content*, to define what elements of the modeling process should be applied at that phase, and
  - Listing the *Model Outcomes*, to develop a form that can be interpreted by stakeholders to demonstrate value (and which may have to be transformed from the model to ease communication).



# Medical System Model Domain

- Representation of the Medical System as an internal component of the CHPS.
- Communicates that the crewmembers are important components *within* the Flight System.
- Promote awareness and understanding of the impacts the integrated human and technical portions of the system have on each other.

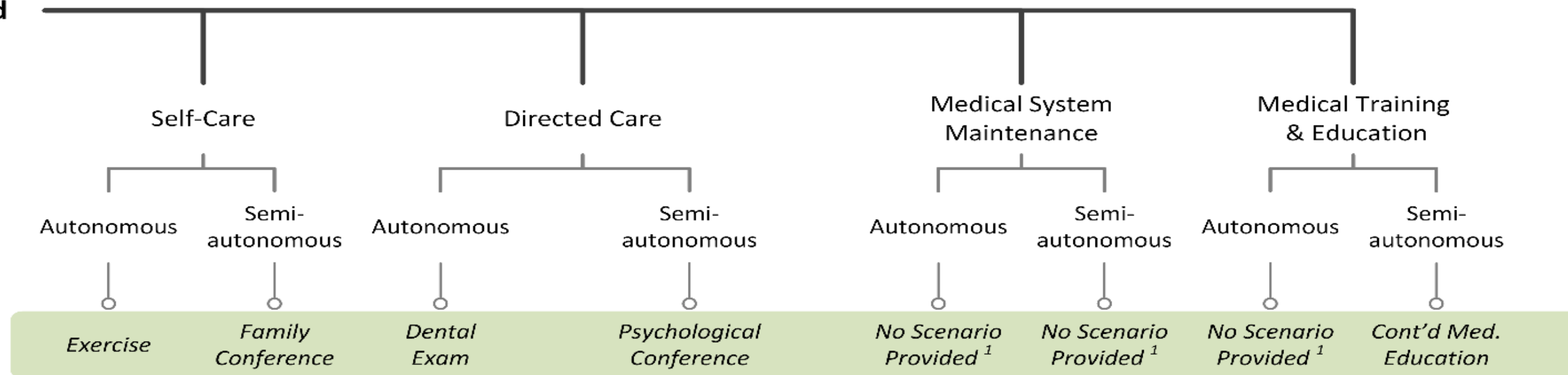




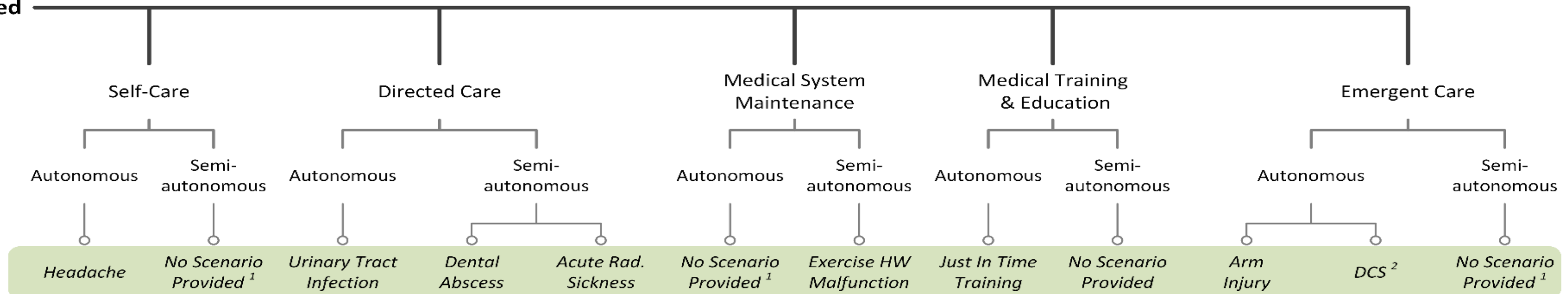
# Concept of Operations

## In-Flight Medical System Scenarios

### Planned



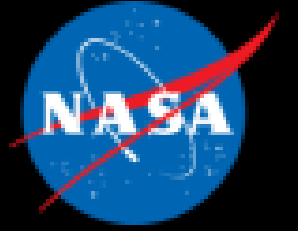
### Unplanned



<sup>1</sup> System functionality is demonstrated in other scenarios

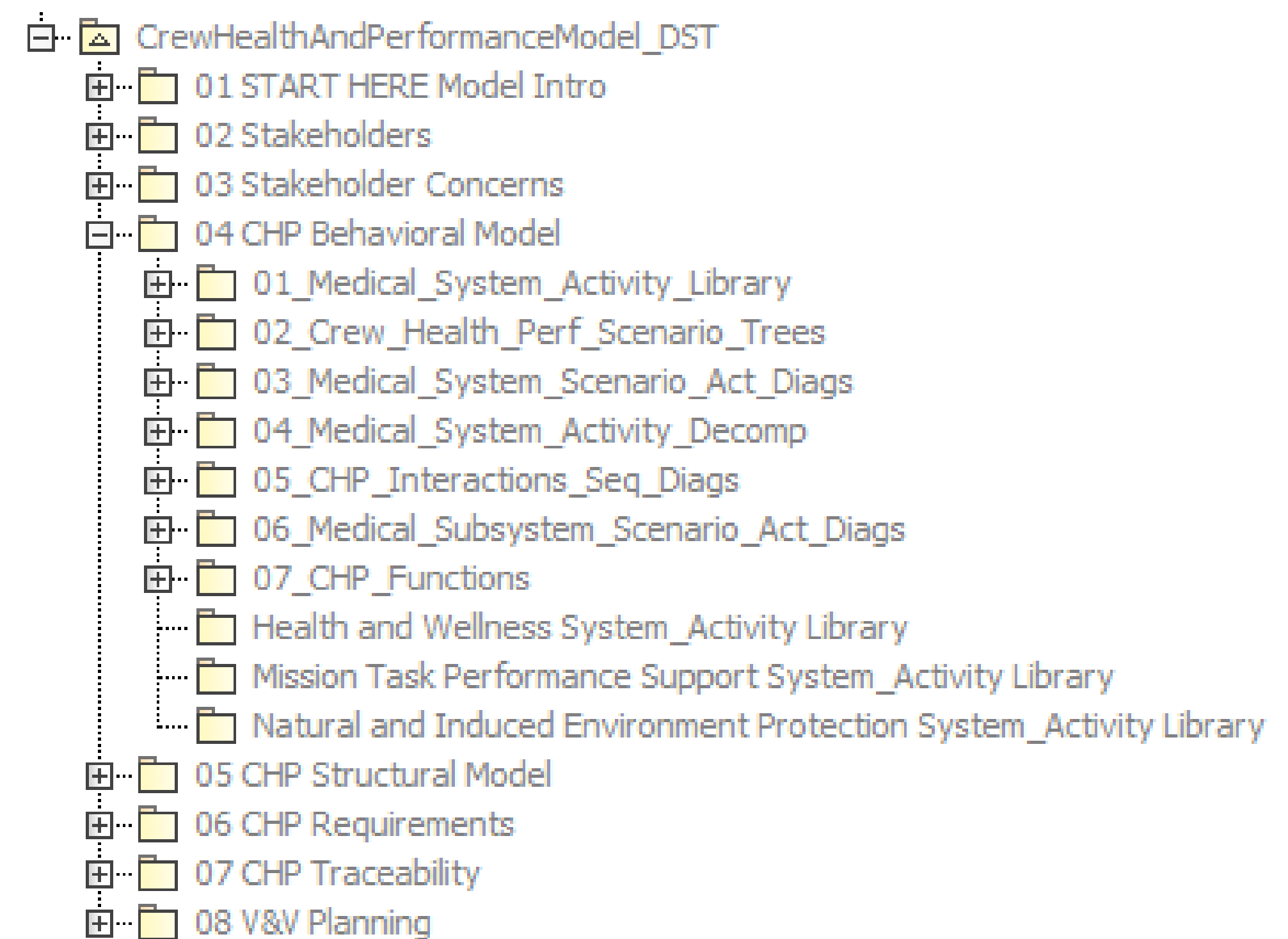
<sup>2</sup> Patient is the physician astronaut

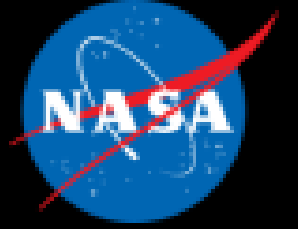




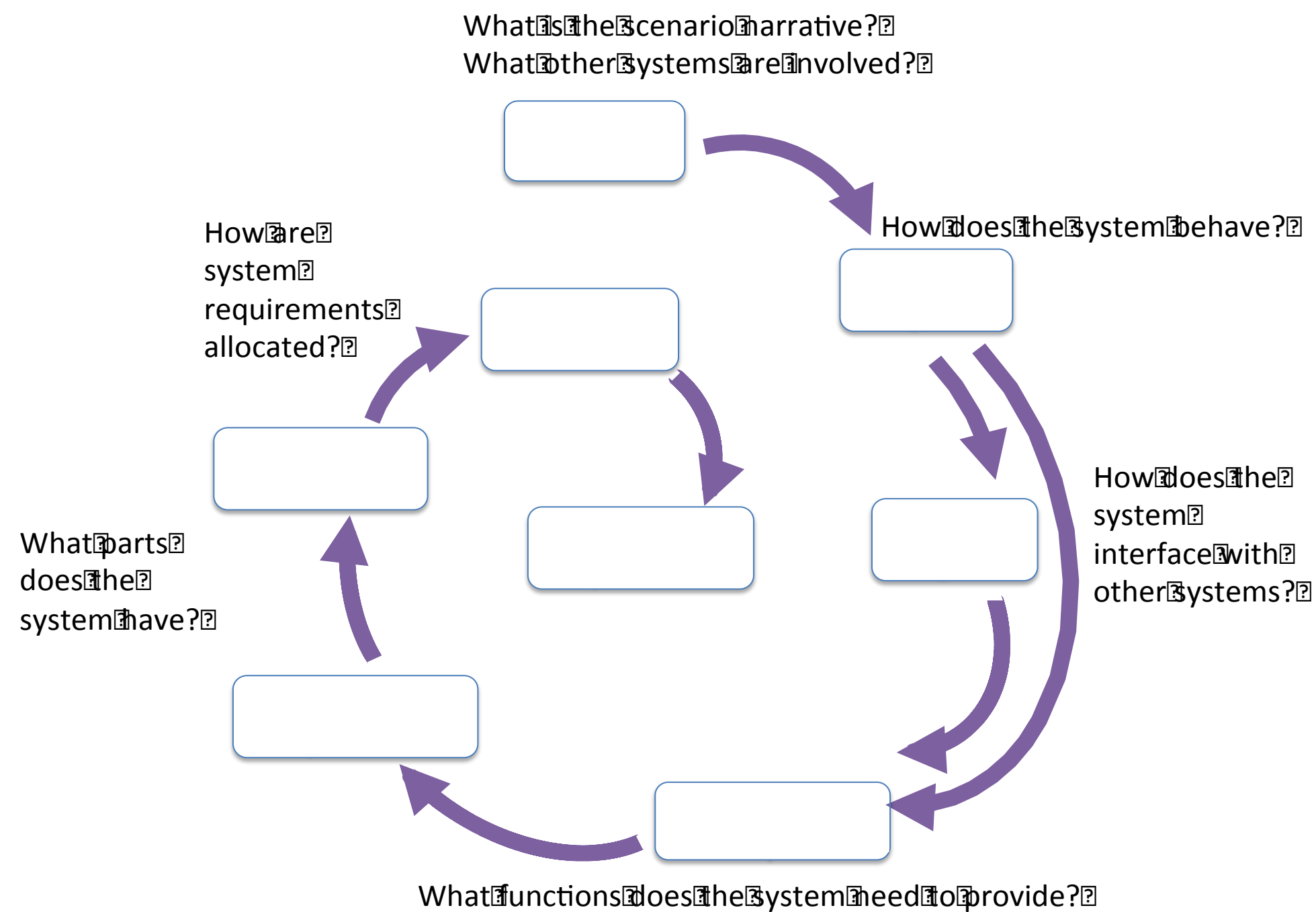
# Model Organization and Containment Tree

- A common template for model organization ensures consistency in development of model products.
- When adopted across teams, this organization makes navigation through shared models easier.
- The Deep Space Transit model is the highest level of modeling fidelity, shorter exploration mission may use a subset of these packages.

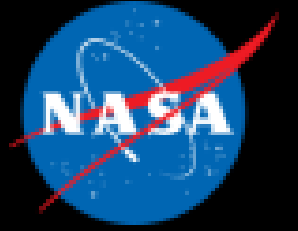




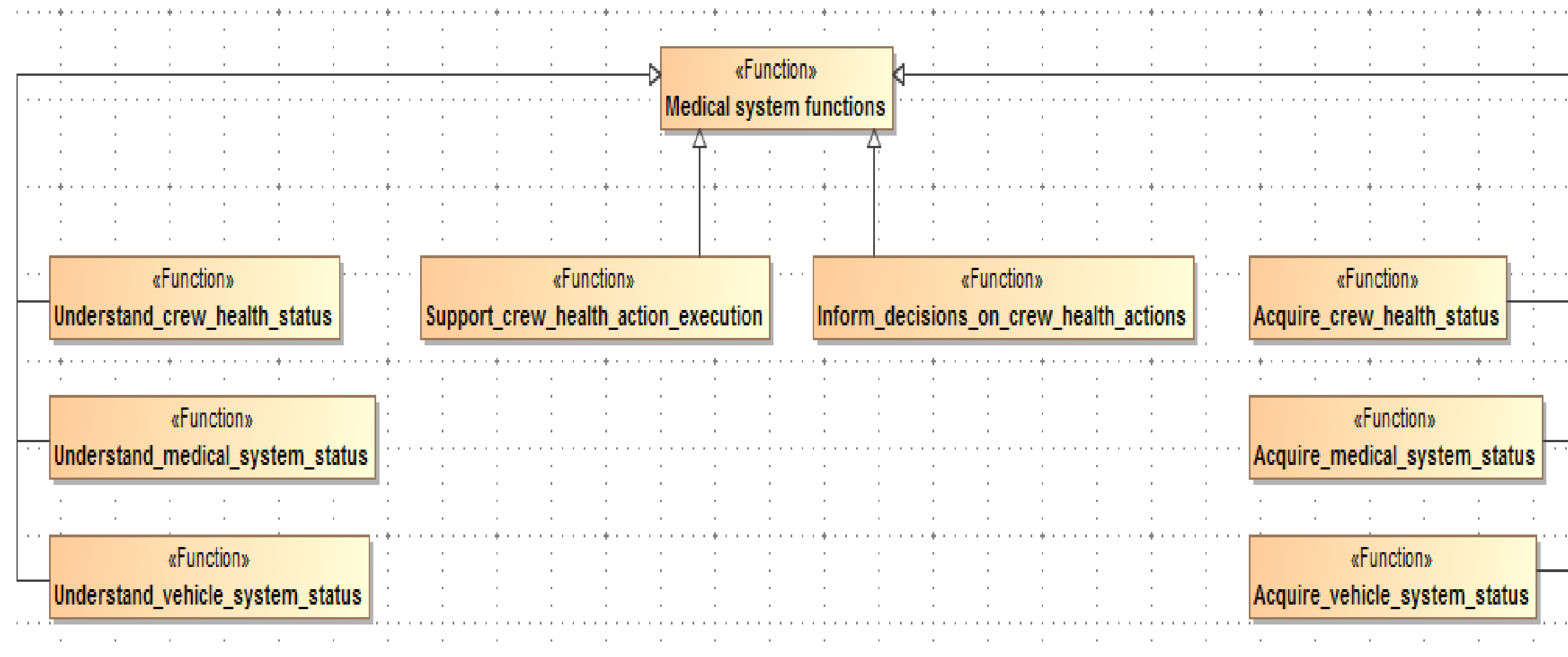
# Model Process



- A modeling process was created for consistency in product development and work flow.
- The use case scenarios from the ConOps were used as the starting point.
- The modeling process shows this activity as a looped and iterative process, which allows for model updates as needs are negotiated and trades are made throughout the project lifecycle.



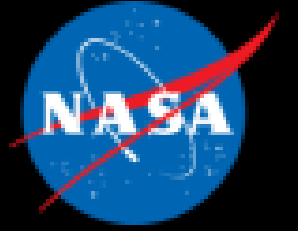
# Functional Decomposition



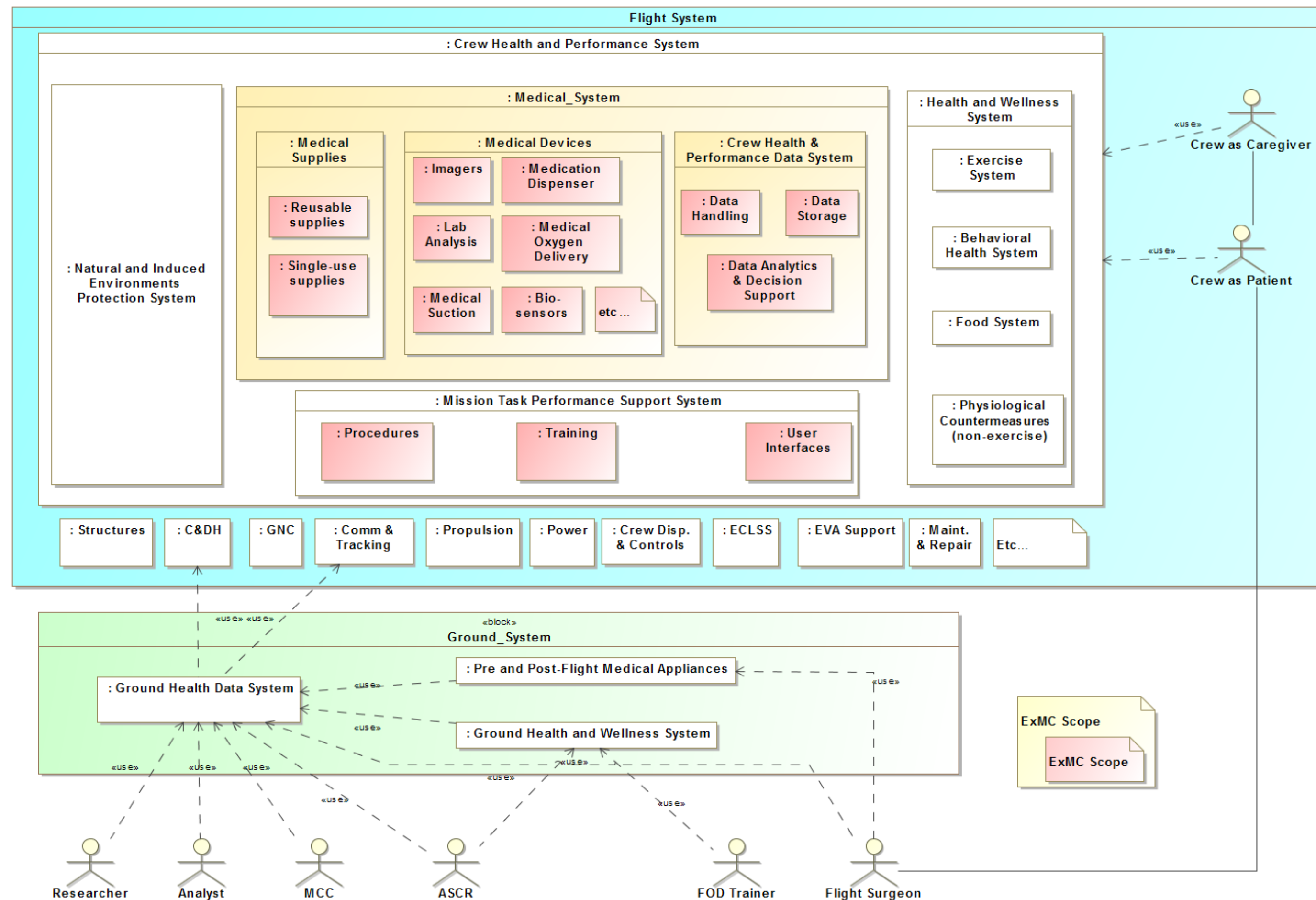
- Thematic analysis<sup>2</sup> was used to identify what the functions were for the medical system.
- *Phase 1 - Familiarization with the data*
- *Phase 2 – Generating initial codes*
- *Phase 3 – Searching for themes*
- *Phase 4 – Reviewing themes*
- *Phase 5 – Defining and naming themes*
- *Phase 6 – Producing the report*

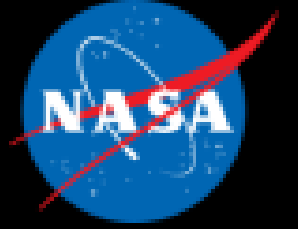
<sup>2</sup>V. Braun, & V. Clark.. Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101. 2006.





# System Architecture Model



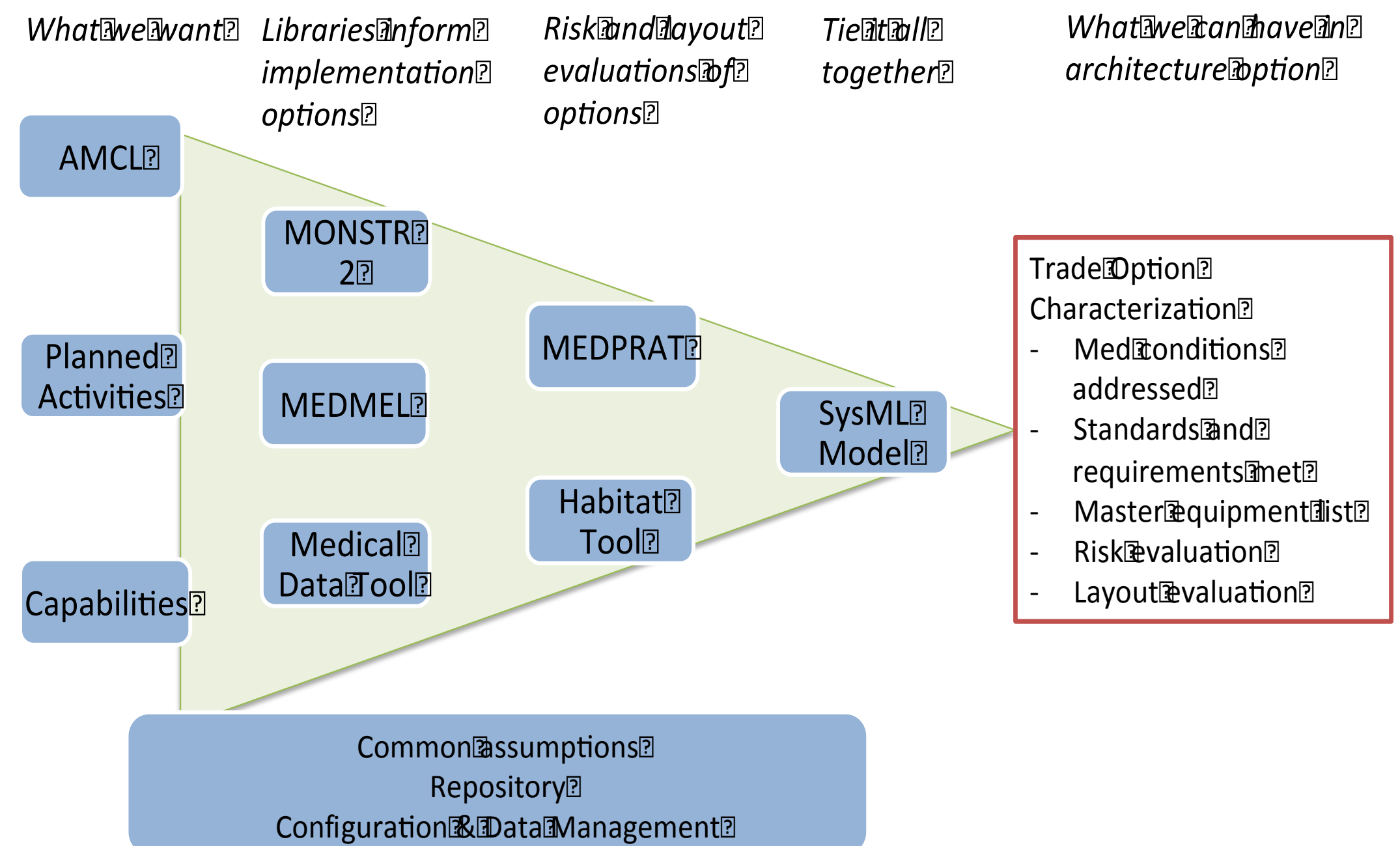


# Next Steps and Applications

## Model Expansion

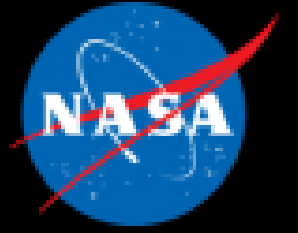
- Interface definitions.
- Customized tools.
- Model libraries.
- Model profiles and stereotypes.
- Style Guide.

## Applications





# Summary



- Successful implementation of any system or subsystem in a complex project, such as a Mars transit vehicle, requires thoughtful and structured design from project initiation through maturation and implementation.
- The MBSE approach and team methodology is key to ensuring consistent workflow, practices, and streamlined integration with vehicle design.

